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TEXTILE WASTE WATER TREATMENT BY CHEMICAL COAGULATION TECHNOLOGY

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Abstract

This investigation deals with studying the parameters affecting coagulation-flocculation behaviour such as coagulant types, dosage and settling time; the results show reduction in COD, TSS, and adjusted pH value using lime with magnesium chloride and alum.

Final results revealed that percent removal of COD 93.3%, percent removal of TSS 92.8% and pH is 8. Better coagulation performance which resulted best COD and TSS removal was acheived using 1g/L CaO with 1 g/L $MgCl_2.7H_2O$ and 250 mg/L $Al_2(SO_4)_3$. In this paper also then effect of intensity and time of mixing was studied.

Finally a treatment process steps were designed and a process flow diagram for the treatment plant was illustrated.

Keywords: Texttile wastewater, Coagulation technology, Lamella settler design.

Introduction

Wastewater from textile industry contains undegradable substances. Textile wastewater causes a big environmental problem due to the huge amounts of effluent generated from textile and dyeing processes [1,2]. So wastewater treatment and reuses of treated effluent in textile industry is a must, especially in countries that suffer from water scarcy [3].

In Egypt textile manufacture is one of the oldest and traditional industries, majorty of manpower is working in this industry from (230,000 – 500,000) according to SUSTEXNET project country reports 2014 [4]. So to save the Nile and other water sources in Egypt, big attention has been focused on textile wastewater treatment.

All over the world several studies have been conducted in this field using different techniques such as wet oxidation [5], adsorbent [6,7], fenton reagent [8], advanced oxidation with biological oxidation [9], granular activated carbons [10,11] and coagulation-electro-oxidation [12].

Textile effluent contains considerable quantities of unfixed dyes (about 20%) [13]. So treatment of finishing and dyeing process effluent represents significant environmental probelms in textile sector [14]. Textile wastewaters are coloured and contain high COD and BOD values, extreme pH and they have different contents of heavy metals, surfactants, salts, mineral oils besides organic dyes, chemicals and others [15].

Some investigations concentrate on textile effluent treatment by destruction of colour by coagulation floculation process using organic natural flocculant [16]. Other studies showed that using combined chemical coagulation, electrocoagulation and adsorption treatment acheive good removal effeciencies of major pollutants [17].
The main aim of this paper is to study treatment of textile wastewater in Egypt applying chemical coagulation technique followed by lamella settler for sedimentation then disinfection to produce clear effluent of good microbial quality and meet environmental standards of water discharge.

Experimental

2.1 Sample Collection and Materials

Composite samples of end - of - pipe effluent were collected from Rotex Dyeing and Finishing Co., 10th of Ramadan. These samples were mixed then stored in refrigerator to assume good representative sampling of the factory effluent. The proposed coagulant are (lime, Ferrous Sulfate Ferric Chloride; Lime - Ferrous Sulfate / Lime -

Ferric Chloride combination, Lime / Magnesium Chloride combination). Investigation of the effect of different variables (pH, dose, rapid & slow mixing time, and settling time) were achieved. Chemicals are fine powder of pure grade while COD vials are from 0-1500 mg/l were purchased from HACH company.

2.2 Experimental Procedure
Chemically assisted primary treatment (CAPT) was applied in treatment of effluent textile wastewater under investigation.

2.2.1 Chemical Coagulation Treatment
Chemical coagulation treatment was performed in a simple jar-test apparatus with controlled speed of six paddles at room temperature. Adding different doses of used coagulant into wastewater sample in test beakers. Fast mixing in the jar-test (80 rpm) for 2 min then slow mixing for 20 min (30 rpm) to allow sedimentation for 30 min. Supernatent of each treated sample was subjected for analysis to evaluate the removal effeciency of each pollutant.

2.2.2 Studied Parameters
Effect of different types of coagulants ($FeCl_3$, $FeSO_4$, $Al_2(SO_4)_3$, CaO, $MgCl_2$) and with different doses and also some combination of these coagulants was investigated. Also varying the intensity besides time of mixing and settling were also studied.

2.3 Analytical Technique
Turbidity, color and COD measurements were performed according to standard methods[18]. Analyses were done using HACH spectrophotometer (model DR/2010). The pH were determined using digital pH meter calibrated using buffer solutions of pH 4.0 and 7.0

2.4 Design Conditions
Waste effluent discharge is 960 m^3/d (40m^3/hr) with pollutants limits shown in table (1)

Table (1) Real waste effluent characteristics

Parameters	Influent real value	Permissible limit*
Flow	40 m^3/ hr	960 m^3/ day
Suspended Solids, mg/l	1120	500
BOD, mg/l	650	400
COD, mg/l	1300	700
Oil and Grease, mg/l	80	100
Turbidity, N.T.U	1140	

*Complying with legislation of the Egypt law 48 of 1982 and the law of 1996 to save the Egyptian environment especially Nile and Water sources.

2.5 Recommended Treatment Components
The proposed treatment unit can be consisted of the following major comonents:

One	(1)	Equalization tank
One	(1)	Flow transmitter
One	(1)	Process feed pump, cast iron construction with level switch control and channel mounted
One	(1)	Central Control Panel with display and numeric input, NEMA 12 design
One	(1)	Reactor tank with mixer mount, FRP construction
One	(1)	Mixer
One	(1)	pH adjustment tank, FRP construction with mixer mount, open top
One	(1)	Mixer

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One	(1)	Single pH control system
One	(1)	Ferric chloride addition system
One	(1)	Lime addition system
One	(1)	Inclined plate clarifier with integral flash mix and flocculation chamber, rated at 0.19 gpm/ft^2
One	(1)	Slurry holding tank, conical bottom

The above unit is provided with different types of pumps, piping, control and instrumentation system.

Results and Discussion

By using different types of coagulant agents with different doses such as ($FeCl_3$, $FeSO_4$, $Al_2(SO_4)_3$, CaO, and $MgCl_2$) it was found the following results.

3.1 Effect of Lime as Coagulant Agent

Applying lime as coagulant agent with different doses from 400 to 1400 mg/l elevated pH from 10.5 to 11.83 and also raised COD and TSS % removal to 80.9% to 82.1% respectively as shown in Figure (1).

From the above figure it is clear that optimum dose of lime was 1000 mg/l because the dose 1400 mg/l had no sensitive effect.

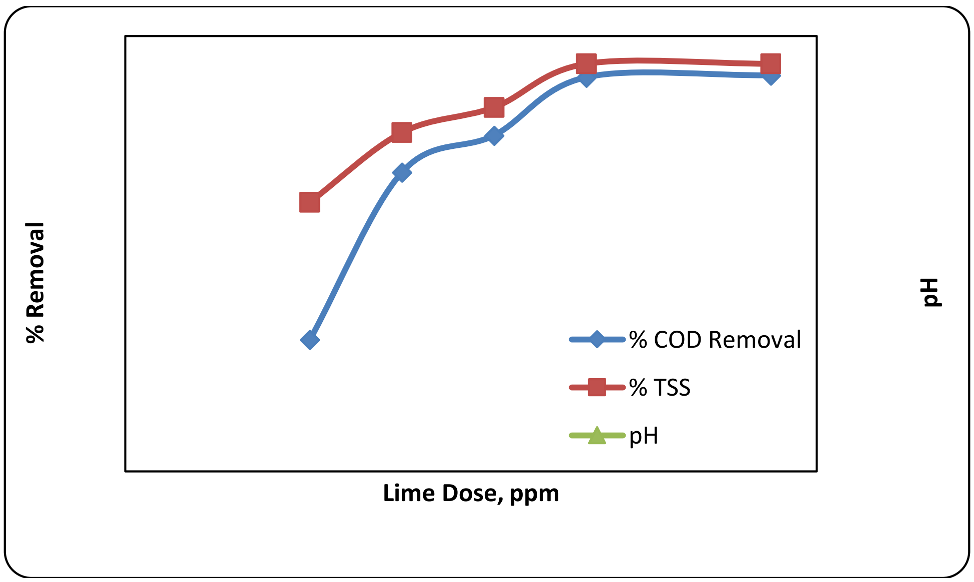

Figure (1) Effect of lime as coagulant agent

3.2 Effect of pH on COD and TSS removal

Trying lime + $MgCl_2.7H_2O$ (1gm/l + 1gm/l) as coagulant at different pH values; were reached 93.8 % and 92.8% removal of COD and TSS respectively at pH = 12 as shown in Figure (2).

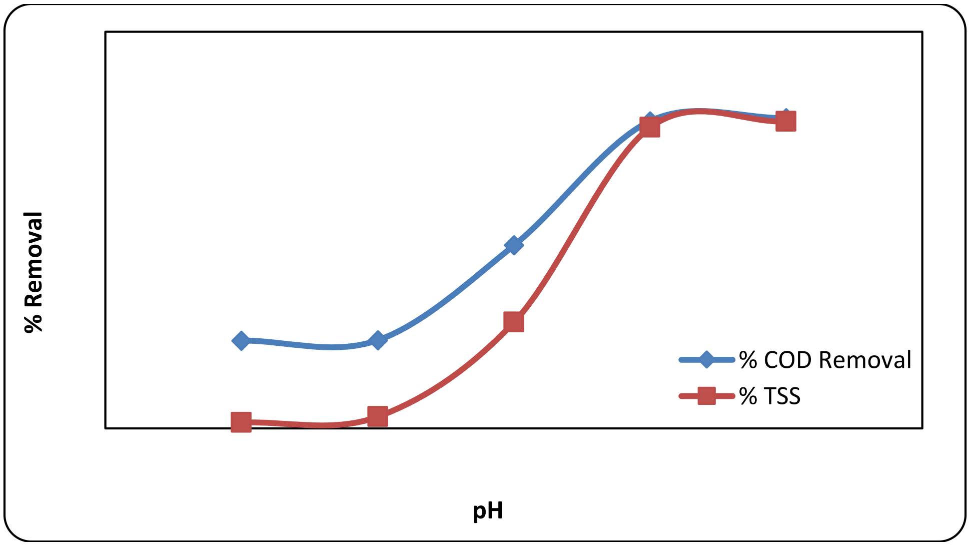

Figure (2) Effect of pH on COD and TSS removal

From figures (1 and 2) addition of 1 gm/l of $MgCl_2.7H_2O$ with optimum dose of lime improved both removal of COD and TSS by 13.1% and 10.7% respectively.

3.3 Using Alum for pH Adjustment
Also best results for COD and TSS removal were obtaind at pH value above 10. So addition of $Al_2(SO_4)_3$ with a dose of 250 mg/l improve the pH to about 8.

3.4 Effect of Mixing
Studying effect of stirring coagulants reveals great effect on COD and TSS removal.

3.4.1 Mixing Intensity
Investigating mixing intensity (80 rpm – 10 rpm) resulting that optimum high mixing was 74 rpm while the optimum low mixing was 30 rpm.

3.4.2 Mixing Time
Also time of high mixing and slow mixing was studied from 1 min to 20 min for both high and slow mixing. It was found that optimum time for flash or high mixing was 2 min while optimum time for slow mixing was 20 min.

3.5 Influence of Settling Time
The effect of settling time was studied from 10 to 60 min and it was found that optimum settling time at which we obtain maximum removal of COD and TSS using optimum coagulant dose was 20 min.

3.6 Process Design
Based on optimum conditions resulted from experimental results from bench and pilot scale, the treated process steps were designed as shown in figure (3).

3.6.1 Design Calculations
Main units of treatment plant are designed considering the following assumptions:

- Maximum flowrate — 960 m^3/day (40 m^3/hr).
- Flash mixing: High mix — 80 r.p.m for 2 minutes
- Slow mixing: Low mix. — 30 r.p.m for 20 minutes
- Settling time — 20 minutes.
- Total Loading — BOD 575 kg/day
  COD 1150 kg/day

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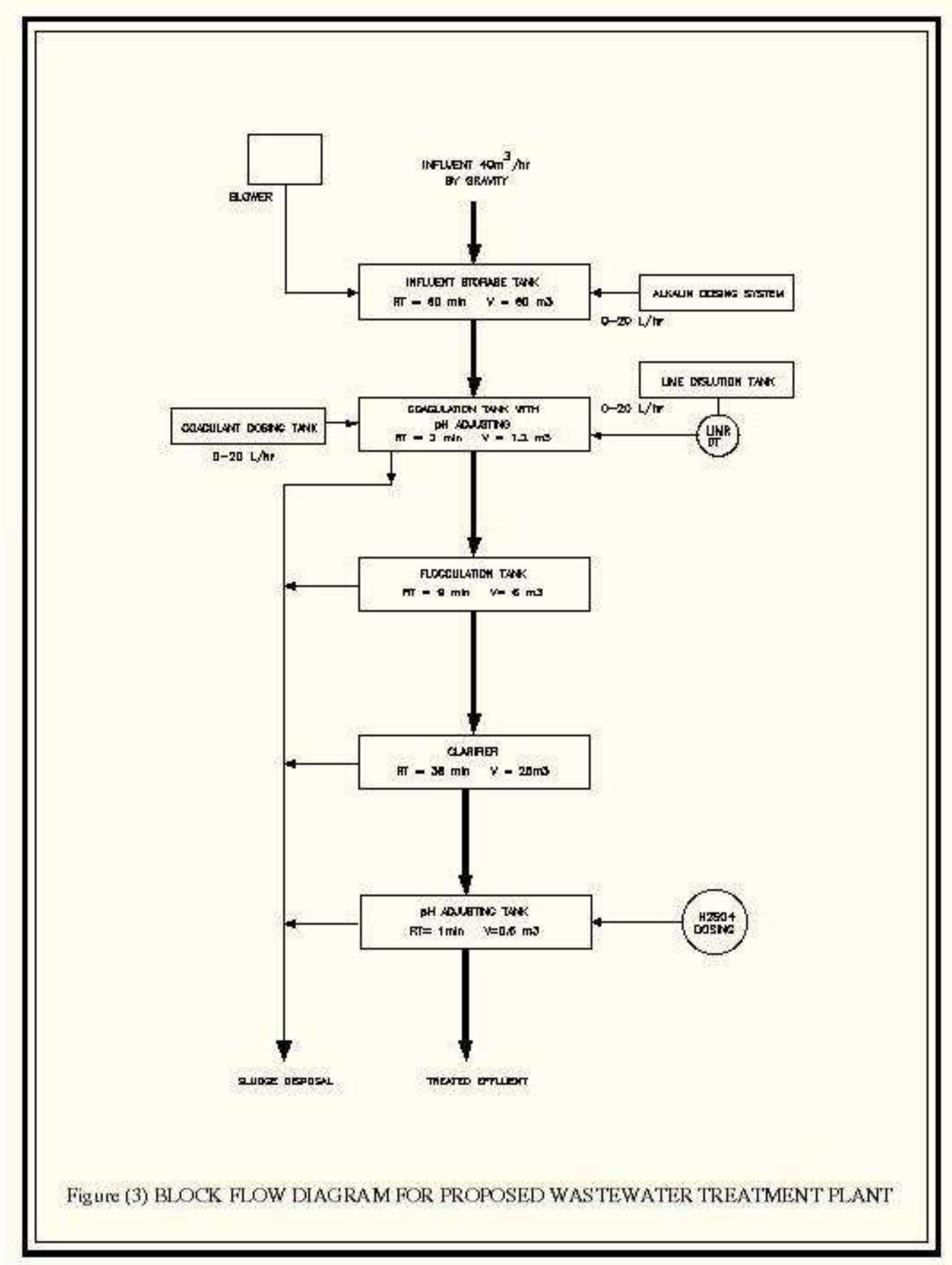

Figure (3) BLOCK FLOW DIAGRAM FOR PROPOSED WASTEWATER TREATMENT PLANT

Figure (3) Block flow diagram for wastewater treatment plant.

The treatment plant is consisted mainly of the following components:

a. Coagulation / Flocculation units

Design considerations:
Assume concentration of Alum = 0.2 ml /l
Daily required Alum = 0.2 x 1000
= 200 l/d
Alum solution concentration (8 %)

$$\text{Total Alum solution per day} = \frac{200 \times 10^3}{40} = 5\ l/m^3/day$$

Storage of alum for 90 days = $1.8\ m^3 \times 1.1 = 1.98 \cong 2\ m^3$
Pump flow for Alum dosing = 0 - 5 l / h
Storage of $MgCl_2$ (S) for 90 days = 13.500 ton
Area required for storage = $13.5 \times 1.1 = 14.9\ m \cong 3.9\ m^2$
Storage of CaO (S) for 90 days = 22.500 ton
Area required for storage = $22.5 \times 1.1 = 24.8\ m \cong 5\ m^2$

Based on the above design considerations the flocculator is a cylindrical tank with inclined bottom of $6m^3$ actual volume and $8m^3$ total volume constructed.

b. Equalization Tank
Considering water flowrate 40 m^3 /hr to required storage 2 hr = 40 x 2 = 80 m^3
Concrete tank (80 m^3) with dimensions 6.7 m x 4 m x 3 m depth.

c. Pumping Station and Mixers
This station collects several pumps and mixers for water and chemicals which are illustrated in table (2).

Table (2) List of pumping station and mixers

No	Description	Qty	Specification
1	Raw Water Pumps	3	40 m^3/ hr Head 10 m (1500 r.p.m.)
2	Lime Recycling Pumps	2	Power: 0.55kw & 4,8 m3/hr Head 23 m
3	Lime Mixers	1	(3HP) 80 r.pm.
4	Chemical Mixers	6	(0.5 HP) 1000 r.p.m.
5	Sludge Pumps	2	(1.5 HP) 10 m^3/hr, head 10 m
6	Dry Pit Raw water Pumps.	3	1 HP 40 m^3 /hr , head 13 m.

d. Sedimentation Tank
This tank is designed for 20 min retention time. It is of rectangular shape with 12m length, 9m width, and 4m depth to give total volume of 432 m^3

e. Lamella Settler Design
The most important equipment in CAPT is the lamella settler so it is designed in details as follows: (hyraulic profile calculation for Lamella Settler)

Flow in pipes:
Assume diameter = 200 mm = 0.2 m
Area = $\pi D^2 / 4$ = $3.14\ (0.2)^2/ 4 = 0.0314$

Flow rate	=	Area . Velocity	
Velocity	=	Flow rate / Area	
Maximum velocity V_{max}	=	80 / 0.314 x 60 x 60	= 0.7177 m/sec
Minimum velocity V_{min}	=	40 / 0.314 x 60 x 60	= 0.3538 m/sec

Using Hazen Williams Formula:

$$S = \frac{hL}{L} = 6.82 \left(\frac{V}{C}\right) 1.85 * \frac{1}{D\, 1.167}$$

C = (Hazen-Williams roughness constant = 140 for steel pipes)
S = slope of the energy grade line
S_{max}. = 2.53 x 10^{-3}
S_{min}. = 6.85 x 10^{-4}

Outlet weir (Free fall weir)

$$Q = \frac{2}{3}\ CL\sqrt{2gH^3}$$

C = 0.624
L = 3.0 m (long /h of weir)
H = head of weir
H_{max} = 0.025 m
H_{min} = 0.016 m

water level max. = (0.025), and min. = (0.016)

Pipeing system between Settler and Flocculator

Friction losses:
Pipe length = 6.6 m
h = S . L
$h_{f,max}$ = (2.53 x 10-3) x 6.6 = 0.01669 m
$h_{f,min}$ = (6.85 x 10-4) x 6.6 = 0.0045 m

These treatment units are illustrated in a process flow diagram shown in figure (4).

Conclusions

From the results of treating textile wastewater using chemically assisted primary treatment (CAPT) it is concluded the following:

1. Treatment of textile wastewater using $MgCl_2.7H_2O$ with lime proved more effeciency than other used coagulant agents.
2. Optimum dose of coagulant agent it 1gm/l lime with 1 gm/l $MgCl_2.7H_2O$ which resulted 93.3% and 92.8% removal of COD and TSS respectively.
3. Alum is not used as coagulant agent but it is also used for wastewater neutralization and pH adjustment.
4. Treatment of textile wastewater with chemical flocculation is still a cost competitive option and it is widely used from the small to large scale factories.
5. Finally from the results of our study CAPT for textile industry effluent reduced the actual settling time to under 30 minutes.

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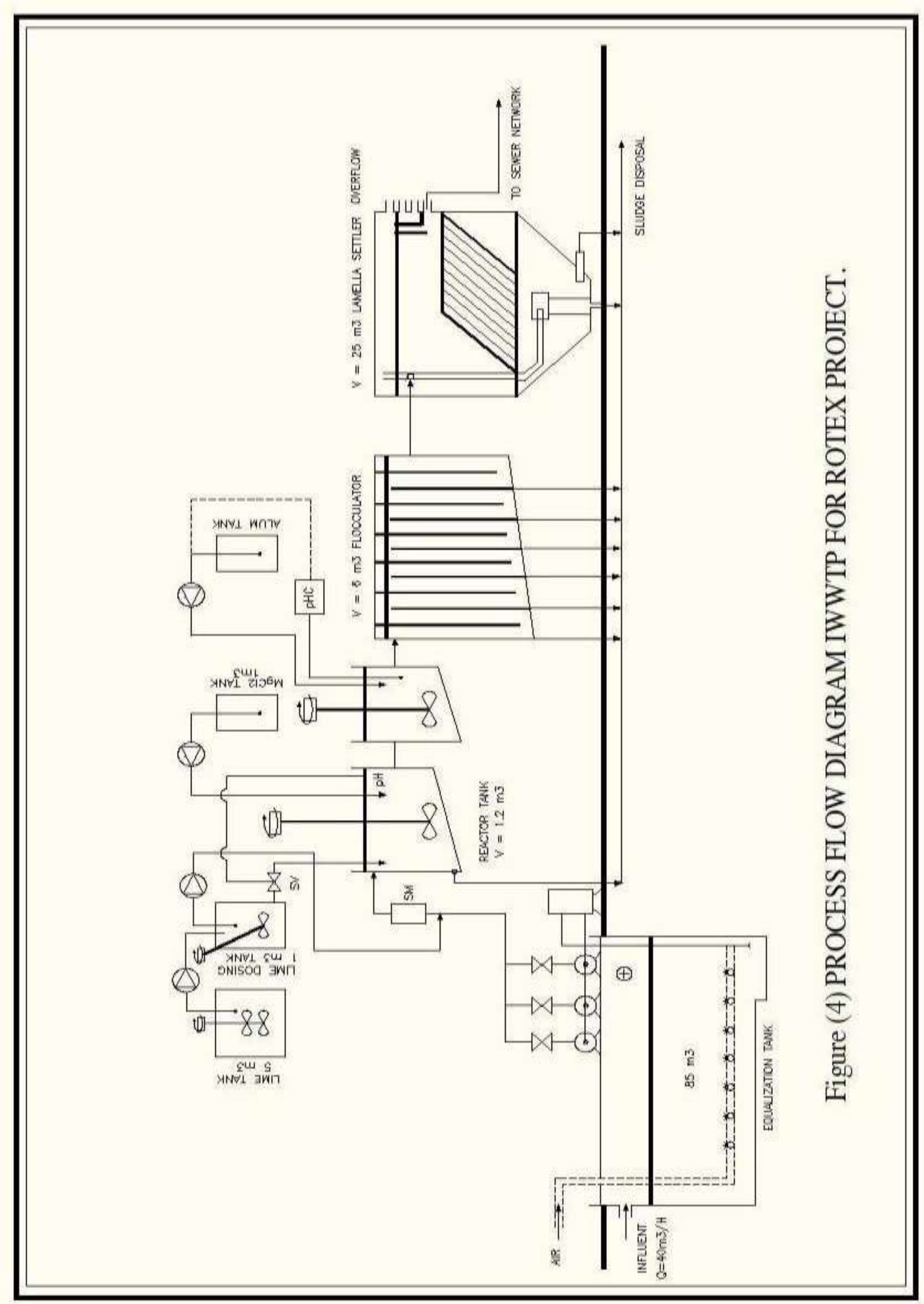

Figure (4) Process flow diagram for wastewater treatment plant.

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